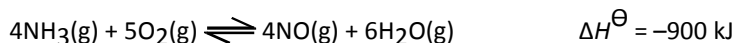


T07D07 – HL 2012 Equilibrium Exam

Name.....

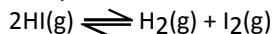
1. Which statements are correct for a reaction at equilibrium?
- The forward and reverse reactions both continue.
 - The rates of the forward and reverse reactions are equal.
 - The concentrations of reactants and products are equal.
- I and II only
 - I and III only
 - II and III only
 - I, II and III
2. Which statement(s) is/are true for a mixture of ice and water at equilibrium?
- The rates of melting and freezing are equal.
 - The amounts of ice and water are equal.
 - The same position of equilibrium can be reached by cooling water and heating ice.
- I only
 - I and III only
 - II only
 - III only
3. Which of the following equilibria would **not** be affected by pressure changes at constant temperature?
- $4\text{HCl(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{H}_2\text{O(g)} + 2\text{Cl}_2\text{(g)}$
 - $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{CO}_2\text{(g)}$
 - $\text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{C}_2\text{H}_5\text{OH(g)}$
 - $\text{PF}_3\text{Cl}_2\text{(g)} \rightleftharpoons \text{PF}_3\text{(g)} + \text{Cl}_2\text{(g)}$
4. The equation for a reaction used in the manufacture of nitric acid is



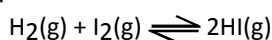
Which changes occur when the temperature of the reaction is increased?

	Position of equilibrium	Value of K_c
A.	shifts to the left	increases
B.	shifts to the left	decreases
C.	shifts to the right	increases
D.	shifts to the right	decreases

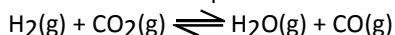
5. The value of the equilibrium constant for the reaction



is 0.25 at 440°C. What would the value of the equilibrium constant be for the following reaction at the same temperature?



- 0.25
 - 0.50
 - 2.0
 - 4.0
6. Hydrogen and carbon dioxide react as shown in the equation below.

For this reaction the values of K_c with different temperatures are

Temperature / K	K_c
500	7.76×10^{-3}
700	1.23×10^{-1}
900	6.01×10^{-1}

Which statement for the reaction is correct?

- The forward reaction is endothermic.
- $\text{H}_2\text{O(g)}$ and CO(g) are more stable than $\text{H}_2\text{(g)}$ and $\text{CO}_2\text{(g)}$.
- The reaction goes almost to completion at high temperatures.
- The reverse reaction is favored by high temperatures.

7. The expression for the equilibrium constant for a reaction is

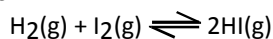
$$K_C = \frac{[B][C]}{[A]^2}$$

At a certain temperature the values of [A], [B] and [C] are all 0.2 mol dm^{-3} . What happens to the value of K_C when all three values are doubled to 0.4 mol dm^{-3} ?

- A. It is halved.
B. It does not change.
C. It doubles.
D. It increases by a factor of four.
8. A 1.0 dm^3 reaction vessel initially contains 6.0 mol of P and 6.0 mol of Q. At equilibrium 4.0 mol of R is present. What is the value of K_C for the following reaction?



- A. 0.11
B. 0.25
C. 0.44
D. 4.00
9. For the reaction below:



at a certain temperature, the equilibrium concentrations, in mol dm^{-3} , are

$$[\text{H}_2\text{(g)}] = 0.30, [\text{I}_2\text{(g)}] = 0.30, [\text{HI(g)}] = 3.0$$

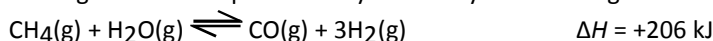
What is the value of K ?

- A. 1.0×10^{-2}
B. 10
C. 33
D. 1.0×10^2
10. A liquid and its vapor are at equilibrium inside a sealed container. Which change will alter the equilibrium vapor pressure of the liquid in the container?
- A. Adding more liquid
B. Adding more vapor
C. Decreasing the volume of the container
D. Decreasing the temperature

(Total 1 mark)

FREE RESPONSE SECTION

11. (a) An industrial gas mixture is produced by the catalytic reforming of methane using steam.

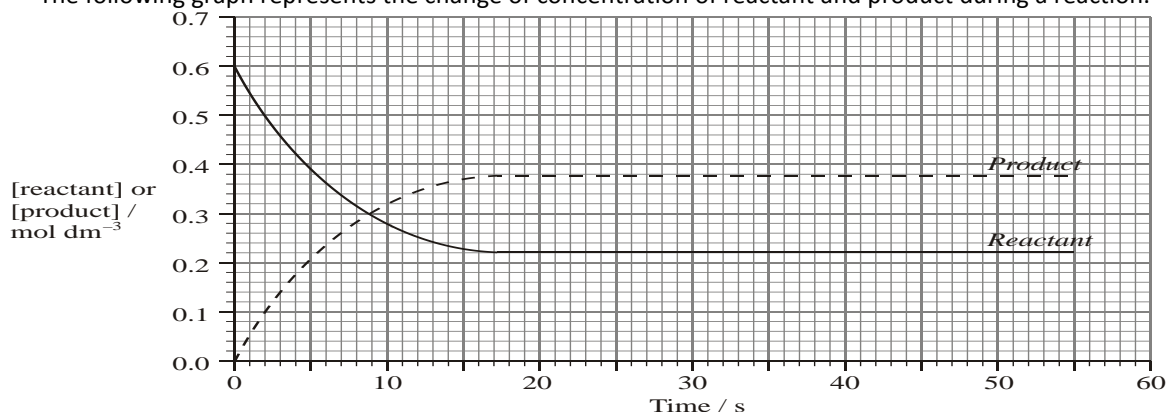


By circling the appropriate letter(s) below, identify the change(s) that would shift the position of equilibrium to the right.

- | | | | |
|---|----------------------------|---|--|
| A | increasing the temperature | B | decreasing the temperature |
| C | increasing the pressure | D | adding a catalyst |
| E | decreasing the pressure | F | increasing the concentration of H_2 |

(2)

- (b) The following graph represents the change of concentration of reactant and product during a reaction.



- (i) Calculate the average rate of reaction over the first 15 s, stating the units.

(3)

- (ii) After 19 s the concentrations of the reactant and product do not change. State what this indicates about the reaction.

(1)

(Total 6 marks)

12. The equilibrium between nitrogen dioxide (dark brown) and dinitrogen tetroxide (colorless) is represented by the following equation.



- (a) Write the equilibrium constant expression, K_C .

(1)

- (b) State and explain the effect of an increase in temperature on the value of K_C .

(2)

- (c) State and explain the visible change that takes place as a result of a decrease in pressure, after equilibrium is re-established.

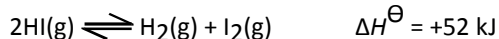
(2)

- (d) Two moles of $\text{NO}_2(\text{g})$ and two moles of $\text{N}_2\text{O}_4(\text{g})$ were placed in an empty 1 dm^3 container and allowed to come to equilibrium at 328 K. Predict, with reference to the value of K_C , whether the equilibrium mixture would contain more or less than two moles of $\text{NO}_2(\text{g})$.

(2)

(Total 7 marks)

13. (a) The equation for the decomposition of hydrogen iodide is



- (b) Deduce the expression for K_c for the forward reaction.

(1)

- (c) The equilibrium formed during this reaction was investigated in two experiments carried out at different temperatures. The results are shown in the table below.

Experiment number	Initial concentration / mol dm ⁻³			Equilibrium concentration / mol dm ⁻³		
	[HI]	[H ₂]	[I ₂]	[HI]	[H ₂]	[I ₂]
1	0.08	0.00	0.00		0.01	
2	0.00	0.08	0.08	0.08		

- (i) For each experiment, deduce the concentrations of the other species present at equilibrium. Calculate the values of K_c for the forward reaction for each experiment.

(6)

- (ii) Use the two calculated values of K_c to deduce which of the two experiments was carried out at the higher temperature, and explain your choice. (If you were not able to calculate the values of K_c in (c)(i), assume that the values are 0.1 for experiment 1 and 0.2 for experiment 2, although these are not the correct values.)

(2)

(Total 15 marks)

14. In the gaseous state, methane and steam react to form hydrogen and carbon dioxide.

- (i) Write an equation for the endothermic equilibrium reaction. Deduce the equilibrium expression for the reaction and state its units.

(4)

- (ii) Deduce and explain the conditions of temperature and pressure under which the forward reaction is favored.

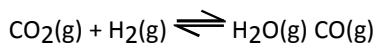
(4)

- (iii) Explain, at the molecular level, why the reaction is carried out at high pressure in industry.

(2)

(Total 10 marks)

15. (a) The following equilibrium is established at 1700°C.



If only carbon dioxide gas and hydrogen gas are present initially, sketch on a graph a line representing rate against time for (i) the forward reaction **and** (ii) the reverse reaction until shortly after equilibrium is established. Explain the shape of each line.

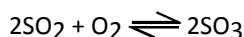
(7)

- (b) K_c for the equilibrium reaction is determined at two different temperatures. At 850°C, $K_c = 1.1$ whereas at 1700°C, $K_c = 4.9$.
On the basis of these K_c values explain whether the reaction is exothermic or endothermic.

(3)

(Total 10 marks)

16. Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (d) in this question.



- (a) Write the equilibrium constant expression for the reaction. (1)
- (b) (i) State the catalyst used in this reaction of the Contact process. (1)
- (ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction. (4)
- (c) Use the collision theory to explain why increasing the temperature increases the rate of the reaction between sulfur dioxide and oxygen. (2)
- (d) Using Le Chatelier's principle state and explain the effect on the position of equilibrium of
- (i) increasing the pressure at constant temperature. (2)
- (ii) removing of sulfur trioxide. (2)
- (iii) using a catalyst. (2)

(Total 14 marks)